UTILIZATION OF A SIMULATIONAL ASSESSMENT OF A FATIGUE DAMAGE PROCESS

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A computer estimation of a fatigue life seems to be a very useful method in the fracture investigation. Problems which are associated with practical procedures are discussed in the paper. An attention is paid to the creation of the chain: simulation of a service loading - continual rainflow counting - fatigue damage evaluation.

The method enables a quick estimation of the residual life of arbitrary complicated structures under various loading and environmental conditions, and it creates a good basis for CAD/CAE technologies and for various expert systems in structural and mechanical engineering.

INTRODUCTION

A fatigue cumulative damage is frequently a decisive cause of structure fractures. Therefore, an assessment of a fatigue damage process is a very important task, and many researches and engineers are solving this problem. Traditional methods, i.e. an experimental investigation in laboratories or in a service, are, however, very expensive and time-consuming. A theoretic-analytical approach is, for a change, too complicated, and it can give only mean estimations. Moreover, such a theoretical estimation is often impossible, owing to a nonlinear character of fatigue damaging and nonstationarity of an operating loading.

Therefore, scientists must look for more effective methods to investigate a cumulative damage in a structure material. A computer-simulational access seems to be a very suitable way to this purpose.

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The basis of the method consists in a creation of a mathematical model of all operational conditions, i.e. service loading, material characteristics, structure parameters and environmental properties. The most difficult problem in this case is to specify a mathematical model of an operating loading.

Using the mathematical model of a service loading, we can simulate a loading process. Then, the simulated service loading must be recalculated into a series of closed hysteresis loops. On the basis of the rainflow counting method, an assessment of a fatigue damage process is performed. Eventually, either a residual life can be predicted or an optimum design can be made or a structure reliability can be evaluated, etc.

THE MATHEMATICAL MODEL OF A SERVICE LOADING

The model must completely respect all statistical characteristics of the loading process (Čačko et. al. (1)). Two basic methods exist to this purpose (Fig. 1). An application of a correlation theory of stochastic processes is the first one. We can describe loading process quite flexibly this way, and a frequency probability density function, power spectral density, cross-correlation function, etc. of the process are respected.

A specification of the model proceeds from experimental data that must be analysed before the simulation procedure. Three ranges of measured data usually exist (Fig. 2). A range of reliable values is the first one. A linear or nonlinear interpolation (e.g. using spline polynomes) is mostly a sufficient processing in this range. The second one - a range of uncertain data - requires a regression analysis. This range represents data which are not numerous, regarding to a restricted sample of measured values. From the processing point of view, the third range is the most interesting one. The range is created by random excesses, and these values must be omitted. Nevertheles, the region must be extrapolated (see Čačko (2)).

The time series method is universal and flexible, especially for nonstationary processes and for discontinuous events. Discontinuous events exist in service loading owing to either various manoeuvres (e.g. cornering, braking, gear change in a vehicles moving) or nonhomogeneous operating conditions (road roughness, air/water turbulence, etc.). Then, the operating loading is usually simulated as a time series with superposed discontinuous events of a poissonian type (Čačko (3)) as it is shown in Fig. 3.

THE CONTINUAL RAINFLOW COUNTING METHOD

It is very important to have a reliable algorithm of counting of closed hysteresis cycles. Classical rainflow methods render possible these procedures only after a definite block of closed loops and they suppose the knowledge of the entire time history before starting to count. In such a case, it is, however, possible neither continual monitoring of a fatigue damage after each cycle nor a running estimation of a residual life during an operation.

The algorithm of a simultaneous signal generation and rainflow counting was proposed by Čačko (4). The method of a simultaneous service process simulation and rainflow counting enables to respect a contribution of each closed hysteresis loop in the stress/strain domain continually, parallelly to the on-line generation of a loading process. This way, a computer memory is saved, and monitoring of damaging is possible, too.

The sequence of the closed cycles can either create a rainflow matrix, or it can be used as an input for various hypotheses of a damage cumulation.

AN ASSESSMENT OF A FATIGUE LIFE

A standard estimation consists in a consideration of rainflow matrices and corresponding fatigue damage per relevant cycles. This method is quite simple and quick, but the rainflow matrix must be extrapolated before a procedure application, and it makes theoretical problems. Also a correct specification of the fatigue damage per each loading cycle is a very serious problem, especially for nonstable materials, regarding to a nonstationarity of damage increments.

A creation of a fatigue damage function is the other possibility. The function depends both on a number of passed closed cycles and on the character of loading, i.e. on amplitudes and mean values of the cycles. Using this method, a continuous monitoring of a fatigue damage process is possible, and the time history is respected, too. The choice of hypotheses of a fatigue damage cumulation is the problem in this case, because a well-known linear Palmgren-Miner hypothesis is frequently not the optimal one, and other hypotheses must be adjusted to a special case, i.e. only one closed cycle is in each block of a macroblock, then.

CONCLUSIONS

The presented procedure can be used in CAD/CAE technologies. An application of the method can be widely developed in many branches of a material research, e.g. structure design, reliability optimisation, residual life prediction, etc. (see Fig. 4).

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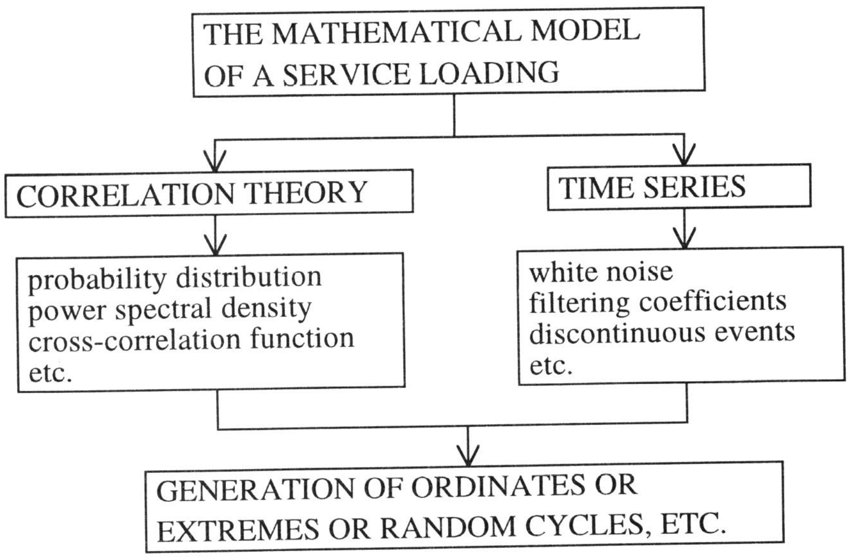

Figure 1 The model of a service loading generation

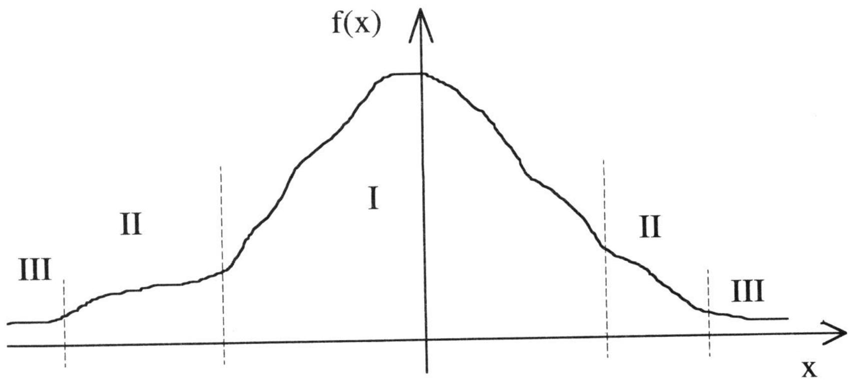

Figure 2 Ranges of measured data

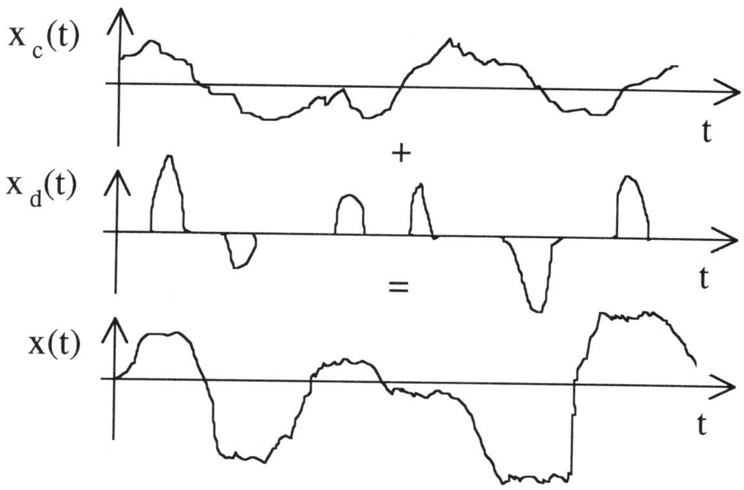

Figure 3 A stochastic process with superposed discontinuous events

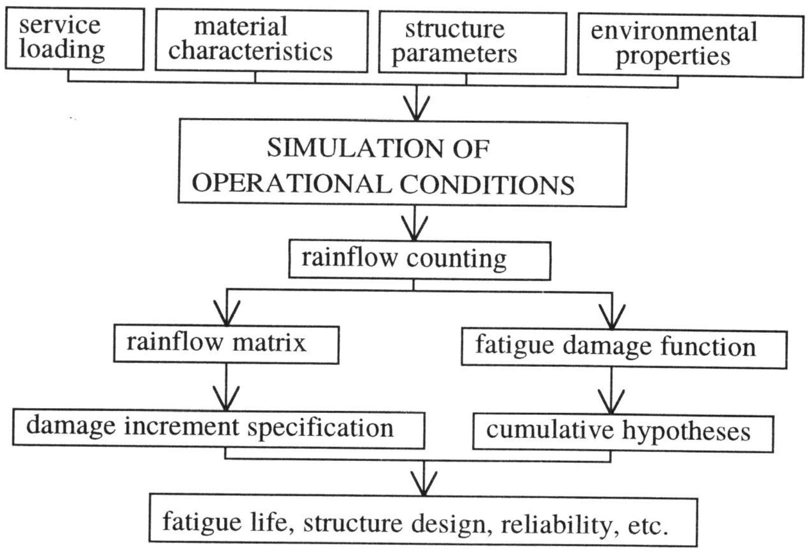

Figure 4 The assessment procedure